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Case Report

Catheter Ablation of a Complex Atrial Tachycardia after Surgical Repair of Tetralogy of Fallot Guided by Combined Noncontact and Contact Mapping

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A 34-year-old man with a surgically repaired Tetralogy of Fallot complained of palpitation, fatigue, and presyncope. A 12-lead ECG showed atrial tachycardia with a cycle length of 250 ms and a P wave morphology positive in leads II, III and aVF, and negative in lead V1. Although the EnSite system (version 6.0J) made use of noncontact mapping to delineate the counterclockwise reentry around the crista terminalis, it was difficult to rule out the incisional atrial reentry because the location of the surgical incision was far from the multi-electrode array. Since the bipolar contact mapping of the EnSite system revealed the location of the atriotomy incision, entrainment mapping during the tachycardia demonstrated the critical reentry circuit around the crista terminalis. Radiofrequency ablation targeting the critical isthmus from the lower position of the crista terminalis to the posterior dense scar which was continuous with the inferior vena cava, and to the atriotomy scar, eliminated the tachycardia. (J Arrhythmia 2010; 26: 38–43)

Key words: Atrial tachycardia, Noncontact and contact mapping, Radiofrequency ablation, Tetralogy of Fallot

Introduction

The mechanisms underlying atrial tachycardia in patients after surgical repair of congenital heart disease has been clarified by using electroanatomical, high resolution mapping systems such as CARTO and EnSite.[1–3] However, both systems have disadvantages. The CARTO system requires sustained tachycardia to completely reconstruct an activation map, and the discriminatory capability of non-contact mapping is reduced at distances greater than 4 cm from the centre of the multi-electrode array of the EnSite system. A more recent version of EnSite system, version 6, provides not only noncontact mapping but also the capability for point-by-point contact mapping. Here we describe a case in which the mechanistic cause of atrial tachycardia was clarified by using simultaneous noncontact and contact mapping.

Case Report

A 34-year-old man with a surgically repaired of Tetralogy of Fallot was admitted to our hospital due to palpitation, fatigue and presyncope. A 12-lead ECG revealed atrial tachycardia with a cycle length of 250 ms and a P wave morphology positive in leads

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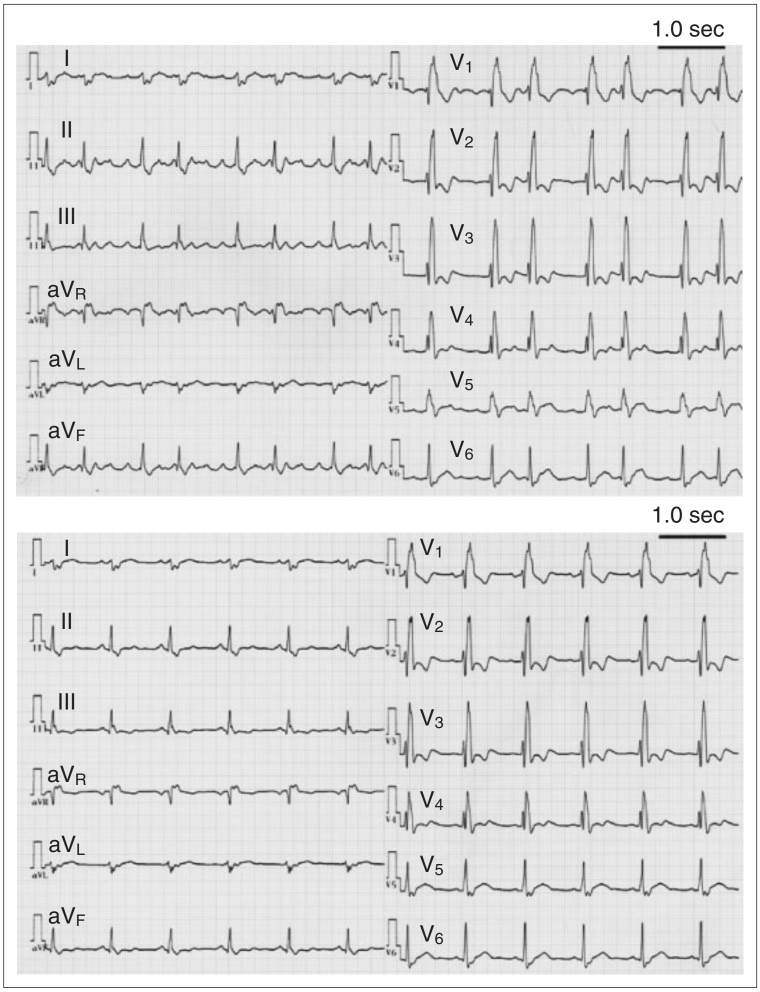

Figure 1
Upper panel: Twelve-lead ECG during the atrial tachycardia. The atrial cycle length was 256 ms with 2:1 to 3:1 atrioventricular conduction; the P wave morphology of atrial tachycardia was positive in II, III, aVF and negative in V1.
Lower panel: Twelve-lead ECG during sinus rhythm after ablation.

II, III and aVF, and negative in lead V1 (**Figure 1**). A chest X-ray showed mild cardiomegaly with a cardiothoracic ratio of 56% without pulmonary congestion. Transthoracic echocardiography confirmed the severe right atrial and ventricular dilatation, with increased right ventricular myocardial wall thickness, and a reduced left ventricle chamber size associated with paradoxical motion of the interventricular septum. Continuous-wave Doppler examination performed from the left apical 4-chamber view identified marked tricuspid insufficiency with the systolic pressure gradient across the tricuspid valve of 49 mmHg.

After written informed consent was obtained, an electrophysiological study was performed in the postabsorptive state under light sedation and free of antiarrhythmic agents.[4] The patient was observed during the tachycardia, which had a cycle length of 256 ms. After internal jugular and femoral vein punctures were performed, a heparin bolus (100 U/kg) was administered, and continuous infusion of heparin was provided thereafter, maintaining an activated clotting time value between 250 and 300 seconds. Surface ECG and bipolar endocardial electrograms were continuously monitored and stored on a computer-based digital amplifier/recorder system for offline analysis (Bard Electrophysiology). Intracardiac electrograms were filtered from 30 to 500 Hz and measured at a sweep speed of 100 mm/s. The electrograms from the His bundle and the coronary sinus were recorded. A multi-electrode array used with the EnSite system (EnSite 3000 with Precision Software, Endcardial Solutions, Inc., St Paul, MN, USA) was introduced into the right atrium through a long sheath. The geometry of the right atrium was constructed with an ablation catheter, a quadripolar bidirectional deflectable catheter with a 4 mm tip electrode (BLAZER II 5031 TK2 Boston EP-Technologies, San Jose, CA, USA). The creation of the isopotential map and local activation time map were carried out through sequential movements of the mapping catheter within the right atrium.[5]

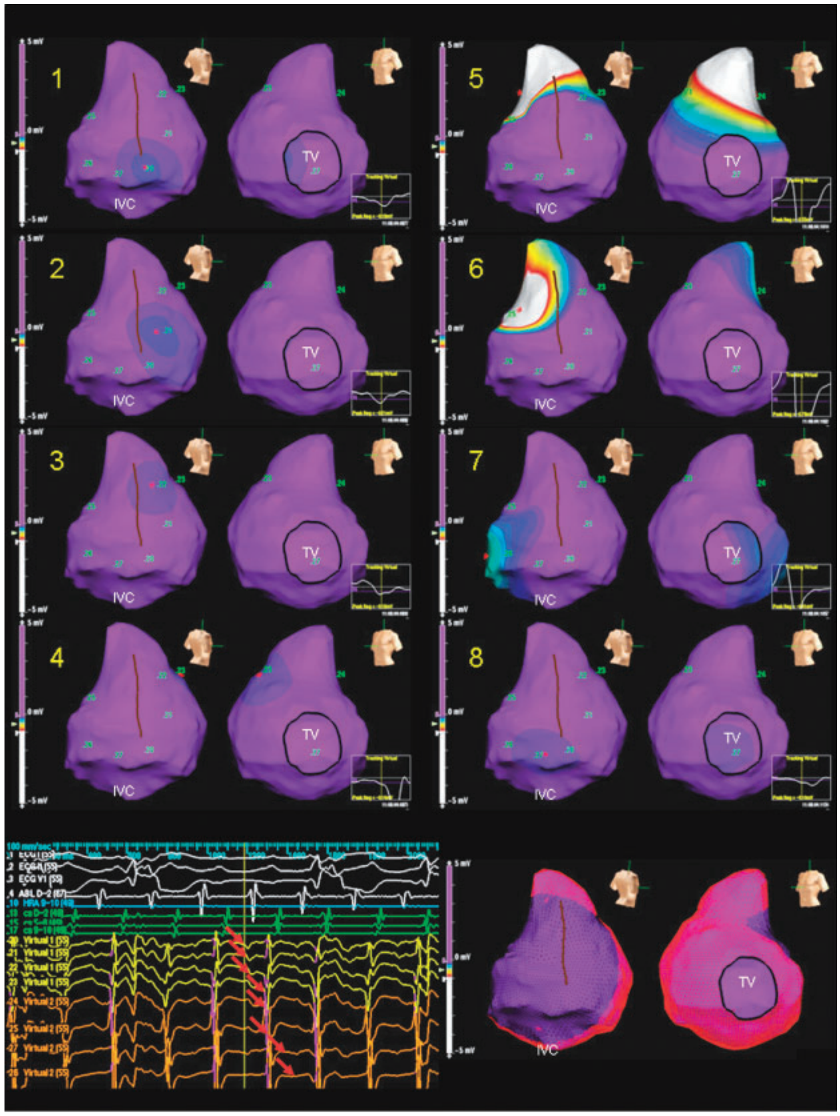

Figure 2
Upper panel: Isopotential maps showing the activation sequence (frame 1 to 8) of the atrial tachycardia in the right posterior oblique (left) and left anterior oblique (right) view. Color scale for each isopotential map has been set so that white indicates most negative potential and blue indicates least negative potential. The activation wave front proceeds through the channel between the lower crista terminalis and the posterior dense scar (frame 1), activates the lateral wall (frame 2 to 3), and rotate around the superior vena cava and upper crista terminalis (frame 4). Then the wave front propagates downward to activate the posterior wall (frame 5 to 7), and spreads over the channel to complete the reentrant circuit (frame 8). Black line indicates crista terminalis. IVC indicates inferior vena cava. TV indicates tricuspid valve.
Lower left panel: Virtual 20 to 23 unipolar electrogram are located anterior to the crista terminalis and virtual 24 to 27 unipolar electrogram are located posterior to the crista terminalis. The virtual unipolar electrograms (red arrows) show continuous sequence of activation, with earliest activation adjacent to latest activation, and the range of activation time is equal to the tachycardia cycle length.
Lower right panel: Right posterolateral (left) and left anterior oblique (right) view of the right atrium represented the geometry grid. Color scale of shiny pink indicates the area more than 4 cm away from the multielectrode array where the virtual electrogram could not be analyzed.

During the analysis of the isopotential map, it became apparent that there was a reentry circuit moving counterclockwise around the crista terminalis, and the lateral and posterior wall of the atrium (**Figure 2**). Because the discriminatory capability of non-contact mapping was reduced at a distance greater than 4 cm from the centre of the balloon catheter, the anterior wall and the site around the tricuspid annulus of the right atrium was outside the range of non-contact mapping capability. Therefore,

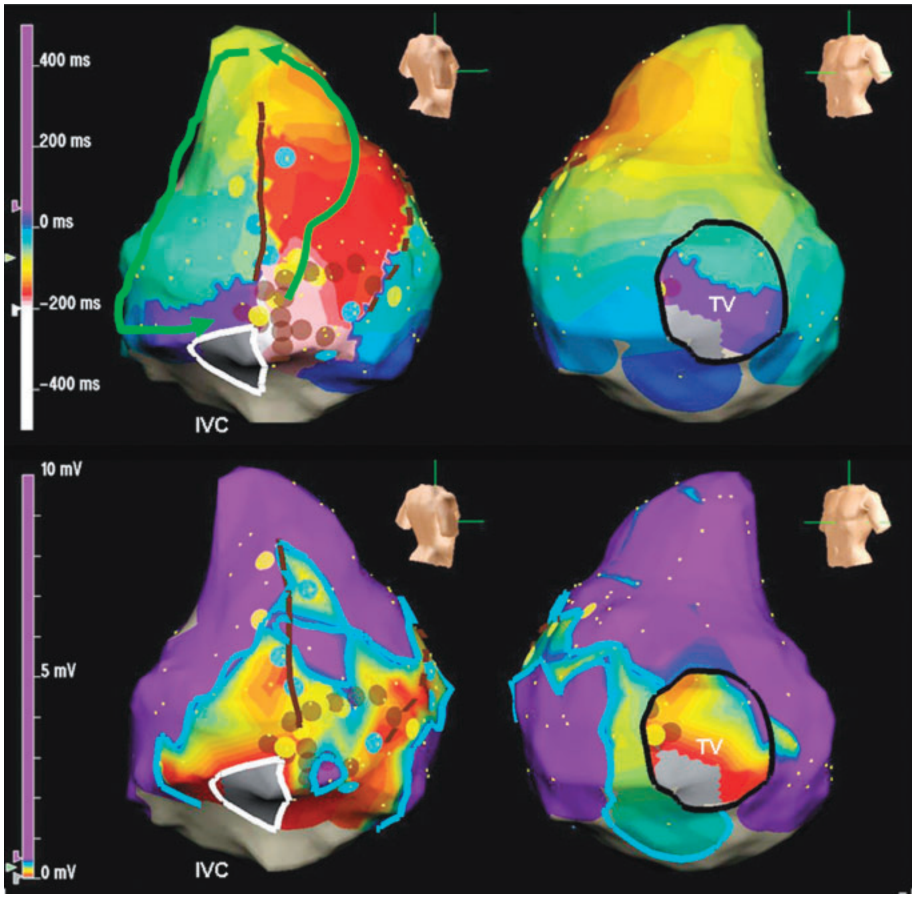

Figure 3
Upper panel: The contact activation map during the tachycardia. The activation wavefront is found to revolve in a counterclockwise manner around the crista terminalis. The colors represent early (white) to late (purple) activation.
Lower panel: The contact bipolar voltage map during tachycardia. Low voltage zone (<0.5 mV) is circled with a blue line. Gray area circled with a white line indicates posterior dense scar (<0.05 mV) which is continuous with inferior vena cava (IVC).
The blue and yellow tags indicate the line of double potentials; the black line indicates crista terminalis and the dotted black line indicates the atriotomy incision. The brown tags indicate the ablation sites. TV indicates tricuspid valve.

it was unclear whether or not those regions were involved in the reentry circuit (**Figure 2**). In addition, the bipolar contact map, which was superimposed on the geometry of the right atrium during the tachycardia, demonstrated the location of the atriotomy incision, and the entrainment mapping combined with three-dimensional electro-anatomical mapping allowed delineation of the complex reentry circuit and the critical isthmus between the crista terminalis and the posterior dense scar which was continuous with the inferior vena cava (**Figure 3**). The local electrogram recorded from the channel between the lower position of the crista terminalis and the posterior dense scar showed the fractionated low amplitude atrial potential (**Figure 4**), entrainment with concealed fusion (same P wave and activation sequence), and a postpacing interval equal to the tachycardia cycle length. Entrainment pacing performed in front of the atriotomy incision during tachycardia showed manifest fusion and a longer postpacing interval with respect to the tachycardia cycle length, indicating the critical circuit of the tachycardia was around the crista terminalis. The tachycardia was successfully ablated through the creation of a linear lesion perpendicular to the wave front conduction, from the lower portion of the crista terminalis to the posterior dense scar and to the atriotomy incision (**Figure 3**). A bi-directional line of block between the crista terminalis and the posterior dense scar was validated by pacing from the septal side of the line and recording of the noncontact isopotential mapping. Tachycardia could no longer be induced either by atrial extra-stimulation or by rapid atrial pacing (up to 300 min^{-1}). The patient remained free of arrhythmias over a 12-month follow up period.

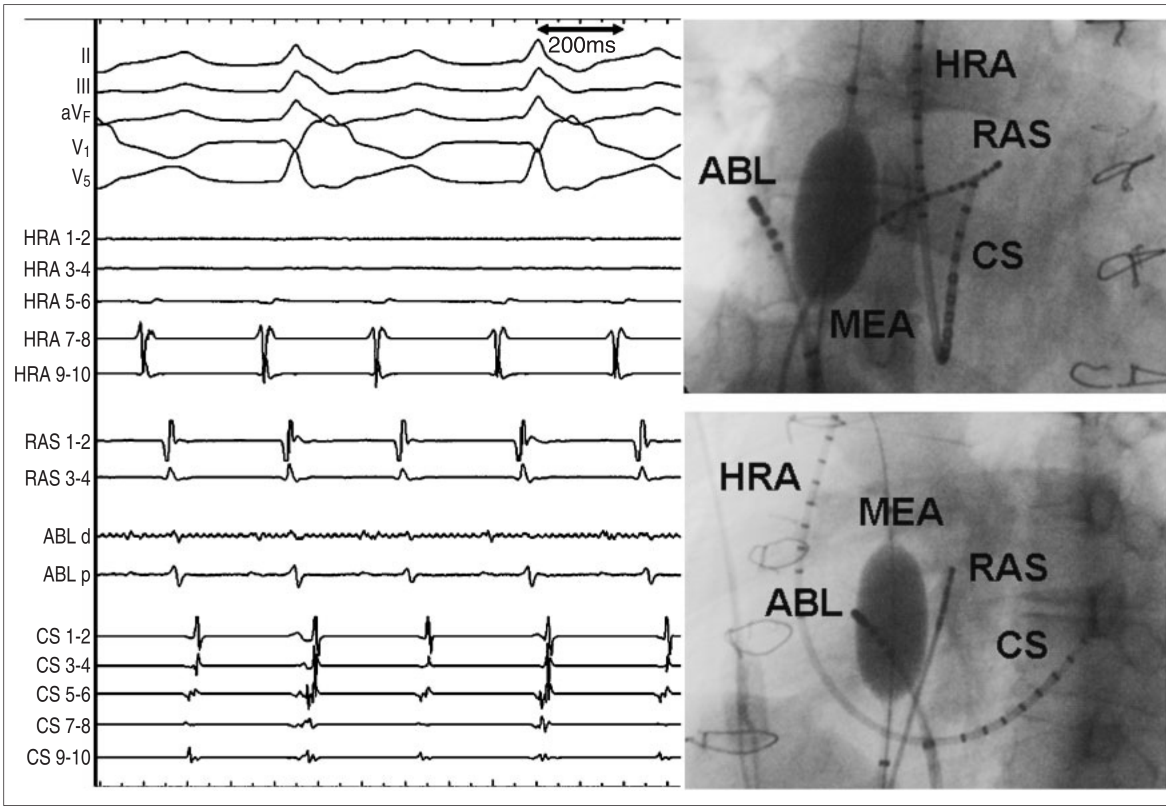

Figure 4
Left panel: Bipolar electrogram at successful ablation site. The local electrogram recorded from the successful ablation site shows the fractionated potentials.
II, III, aVF, V1, V5: surface electrocardiographic leads II, III, aVF, V1, V5, ABL d: distal electrogram of the ablation catheter, ABL p: proximal electrogram of the ablation catheter, CS: coronary sinus, HRA: high right atrium, RAS: right atrial septum
Right panel: Successful ablation site of the right anterior (upper) and left anterior (lower) oblique views of the fluoroscopic right atrial imaging.
ABL: ablation catheter, CS: decapolar electrode catheter in the coronary sinus, HRA: decapolar electrode catheter of the high right atrium, MEA: multielectrode array balloon catheter of EnSite system version 6, RAS: octapolar electrode catheter of the right atrial septum

Discussion

Here we describe the case of a patient with atrial re-entrant tachycardia around the crista terminalis, which was mapped and successfully ablated with the assistance of the EnSite noncontact and contact mapping system. The critical isthmus was located between the lower portion of the crista terminalis and the posterior dense scar which was continuous with the inferior vena cava, and the lateral edge of the atriotomy incision.

The incidence of arrhythmias following congenital heart surgery depends on the type of procedure and duration of follow-up. A Japanese multicenter study, which is a nationwide multicenter study with 512 operative survivors of Tetralogy of Fallot followed for 30 years, has demonstrated that 54 patients (10.5%) had clinically important arrhythmias including 23 patients with bradycardia, 2 with sustained ventricular tachycardia, 18 with ventricular arrhythmias related to syncope, 8 with atrial fibrillation or flutter, and 5 with atrial or supraventricular tachycardia.[6] The prevalence of serious arrhythmias, especially atrial tachycardia, has been low in Japanese patients with Tetralogy of Fallot.

Several reports have demonstrated the mechanism of atrial tachycardia by use of an electro-anatomical mapping system or high resolution mapping system. Nakagawa et al[1] utilized the CARTO system to localize the reentry circuit of atrial tachycardias that occurred after the surgical repair of congenital heart disease. They clarified that macroreentrant right atrial tachycardia after surgical repair of Tetralogy of Fallot required a large area of low voltage containing more than 2 dense scars or a dense scar and a line of double potential forming narrow channels, and that ablation within the channels eliminated the tachycardias. Paul et al[3] reported that the reentrant circuit of atrial tachycardias after the surgical correction of congenital heart disease could be characterized and localized with respect to anatomic landmarks such as atriotomy scars, intra-atrial patches/baffles, and cardiac structures by the use of the noncontact mapping system. In this case, although the right atrium was markedly dilated because of the surgical repair of the Tatralogy of Fallot, the EnSite system (version 6.0J) with noncontact and contact mapping allowed for localization of the tachycardia circuit and provided guidance for effective radiofrequency current delivery.

In conclusion, this case demonstrates that simultaneous noncontact and contact mapping using a single system is useful for ablation of atrial tachycardia arising from the enlarged right atrium after surgical repair of congenital heart disease, since the advantages of both techniques complement each other and enable a more complete understanding of the mechanism of the tachycardia.

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